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Influence of Structure on Complexity
Complexity Management Strategies
Strategies of Air Traffic Controllers
Controllers

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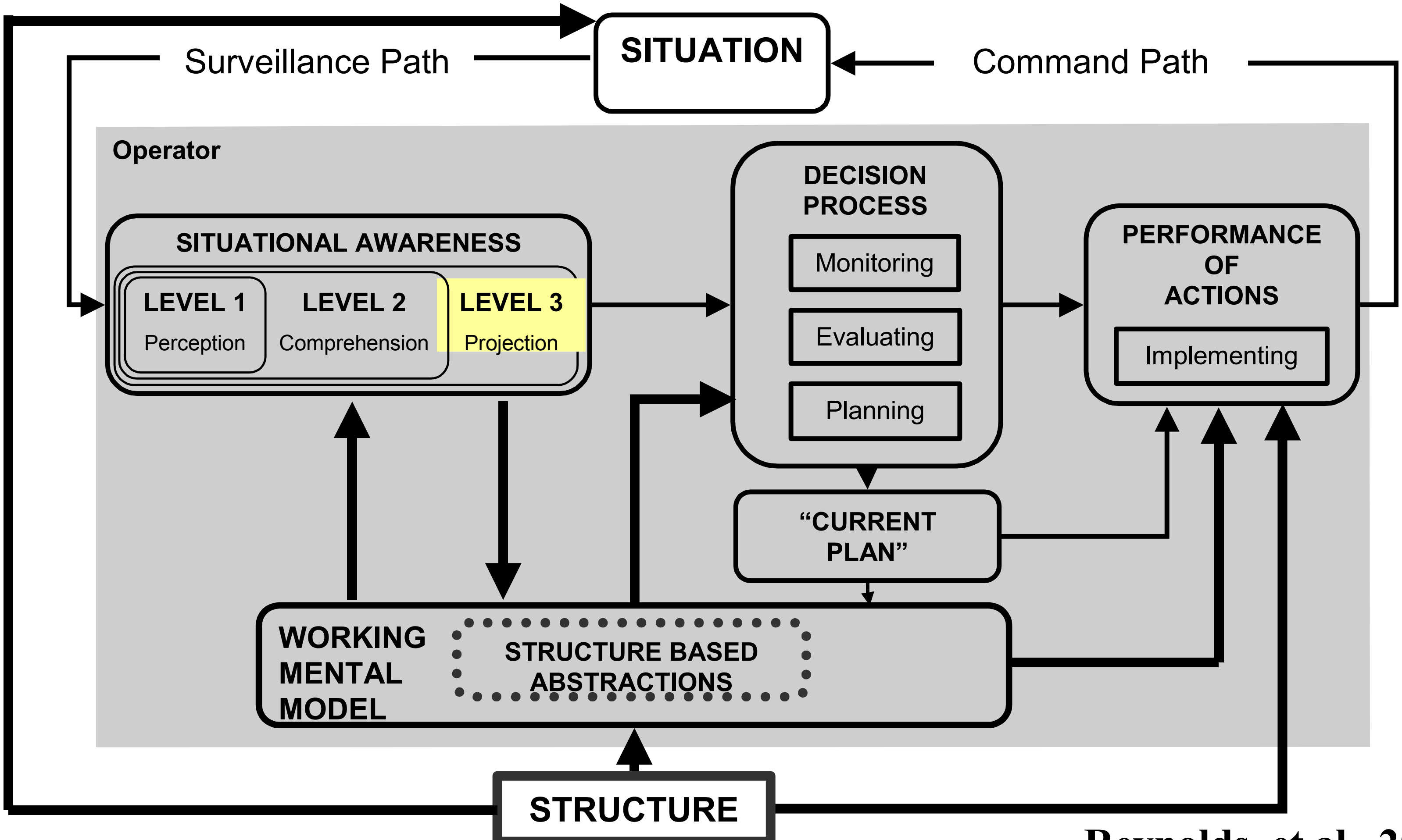
Motivation

- Need for a clear understanding of how air traffic controllers manage the complexity of the situation within their airspace to aid the design of:
  - Decision support tools
  - Information systems
  - Restructured airspace

Methodologies

- Exploratory Field Study at Boston TRACON
  - Investigated use of structure in projection task
- Modeling efforts based on field observations
- Initial voice communications analyses to investigate hypotheses

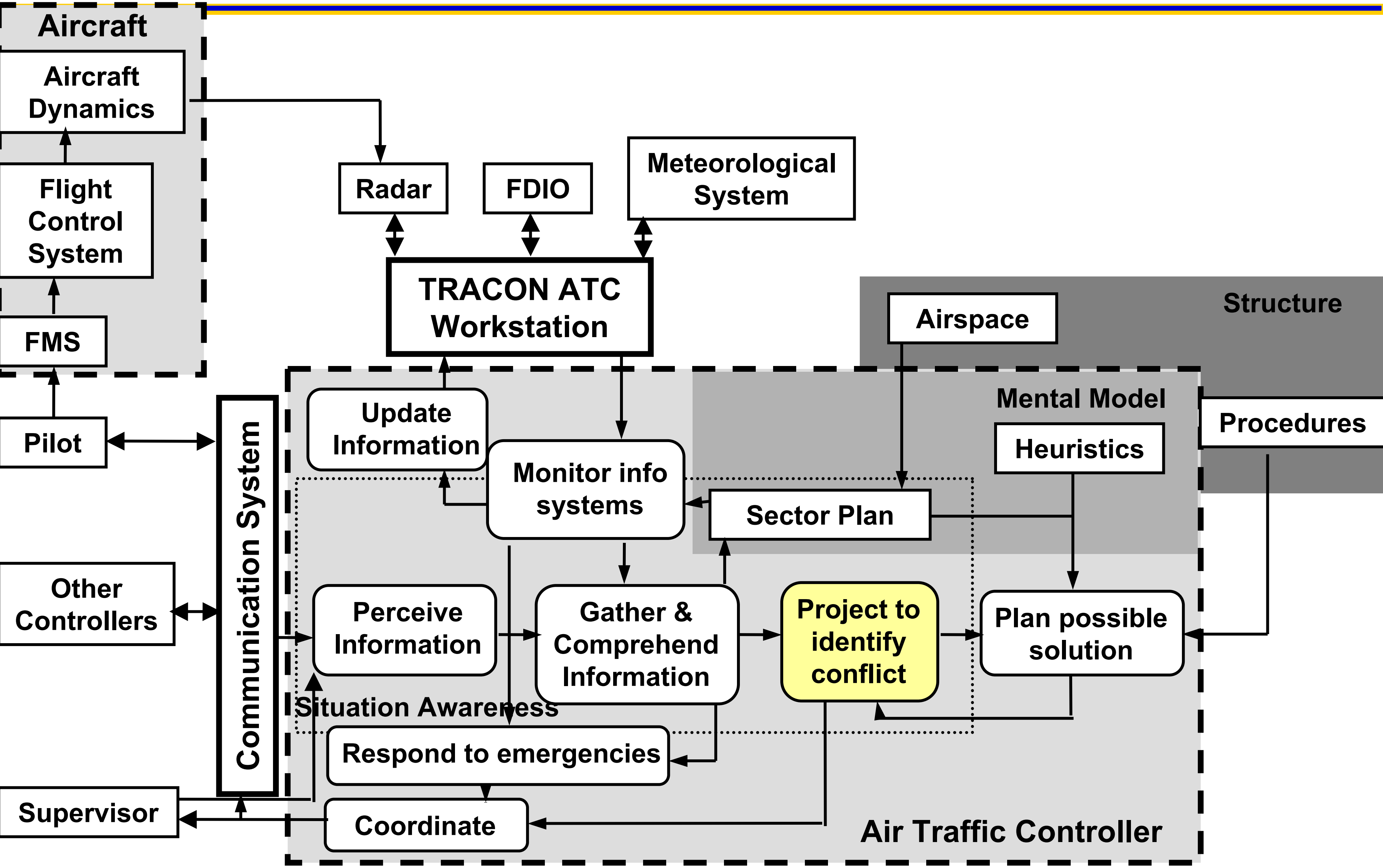
Process Model



Reynolds, et al., 2002

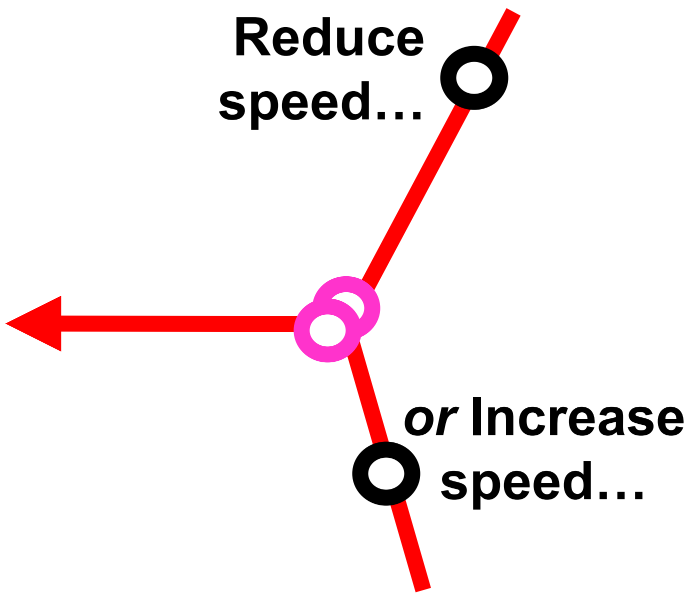
- Focus of complexity management investigation will be on the projection task

TRACON ATC Process Model



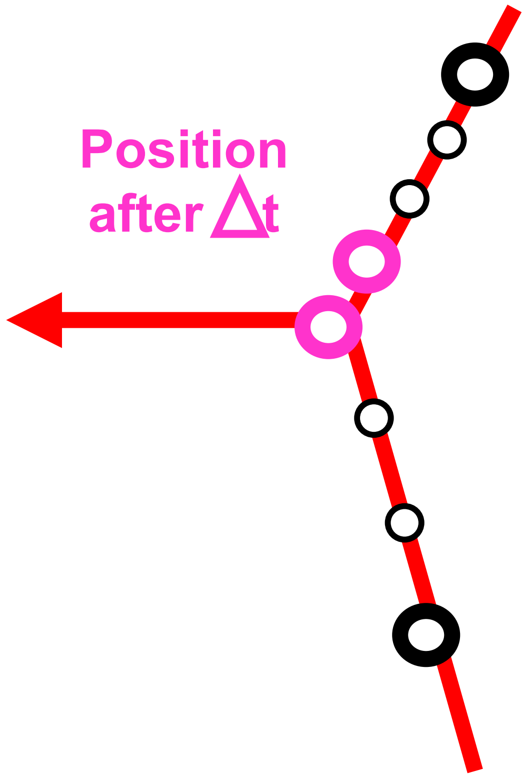
Possible ATC Projection Strategies

- Aircraft relative strategy
  - Clear aircraft for same speed across sector such that with each time update, all aircraft progress equally relative to one another
- Target timing strategy
  - Clear individual aircraft with speeds such that aircraft approach a critical point in sequence with ample separation



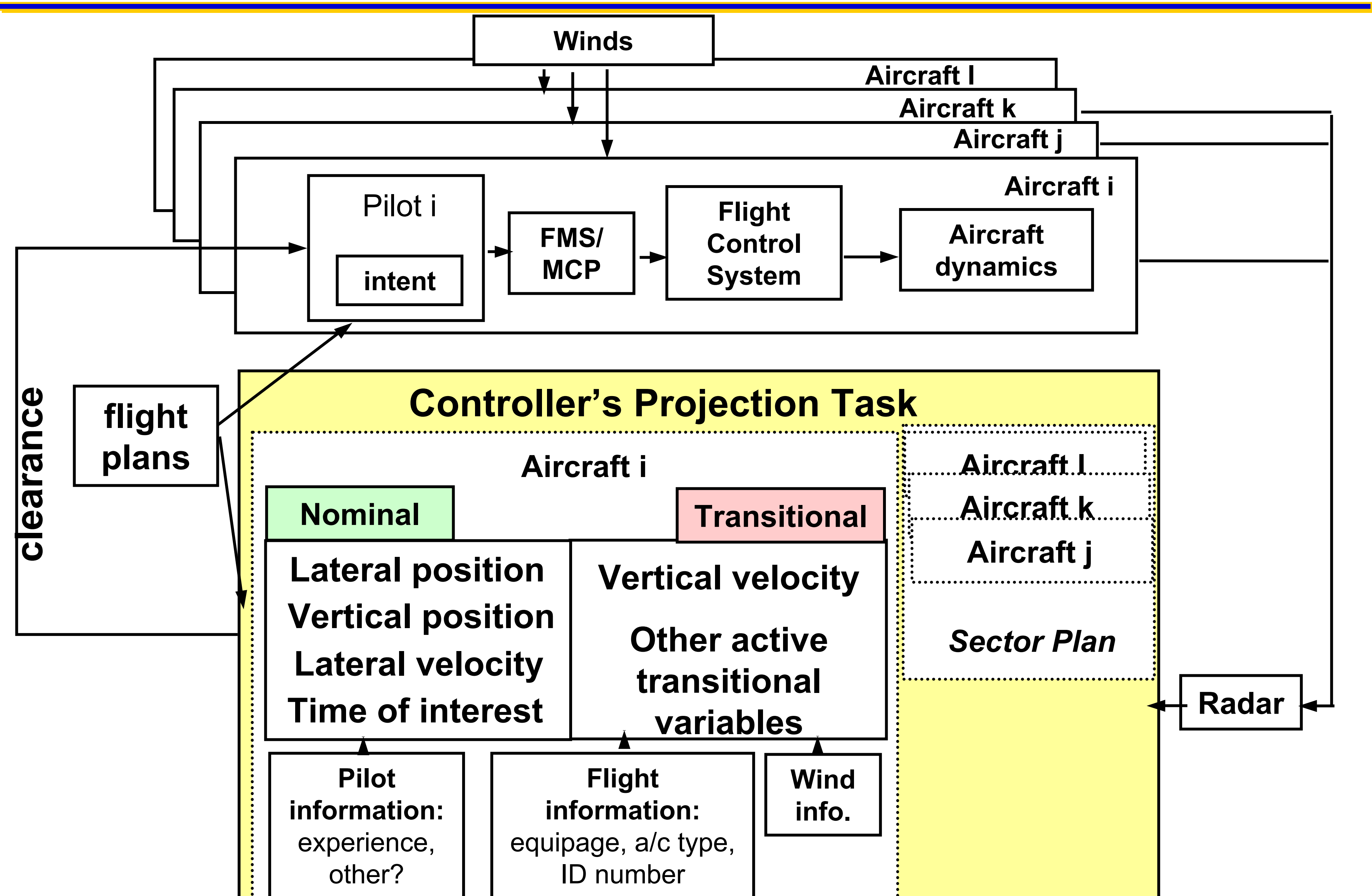
Position Projection in ATC

$$\begin{pmatrix} \begin{matrix} P(x) \\ P(y) \end{matrix} = \begin{matrix} \text{Lateral} \\ \text{position} \end{matrix} \\ \\ P(z) = \begin{matrix} \text{Vertical} \\ \text{position} \end{matrix} \end{pmatrix} + \begin{pmatrix} \begin{matrix} V(x) \\ V(y) \end{matrix} = \begin{matrix} \text{Lateral} \\ \text{velocity} \end{matrix} \\ \begin{matrix} V(z) = 0 \text{ (for} \\ \text{non-transitional} \\ \text{behaviors)} \end{matrix} \end{pmatrix} \Delta t$$



- Δt is the time of interest
  - projected trajectory until P(x,y,z) equals another aircraft's position or until aircraft reaches target point

Projection Task of the Controller

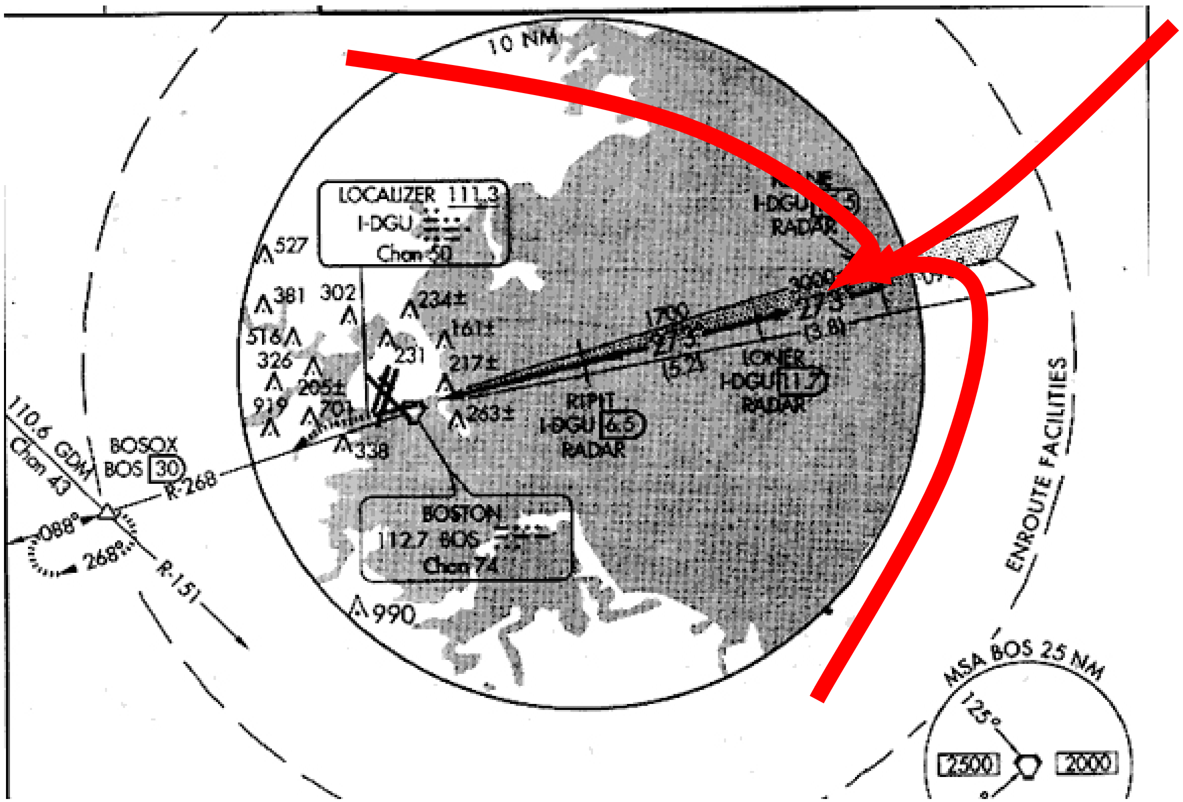


Research Hypothesis

- Initial findings from preliminary field study suggest that:

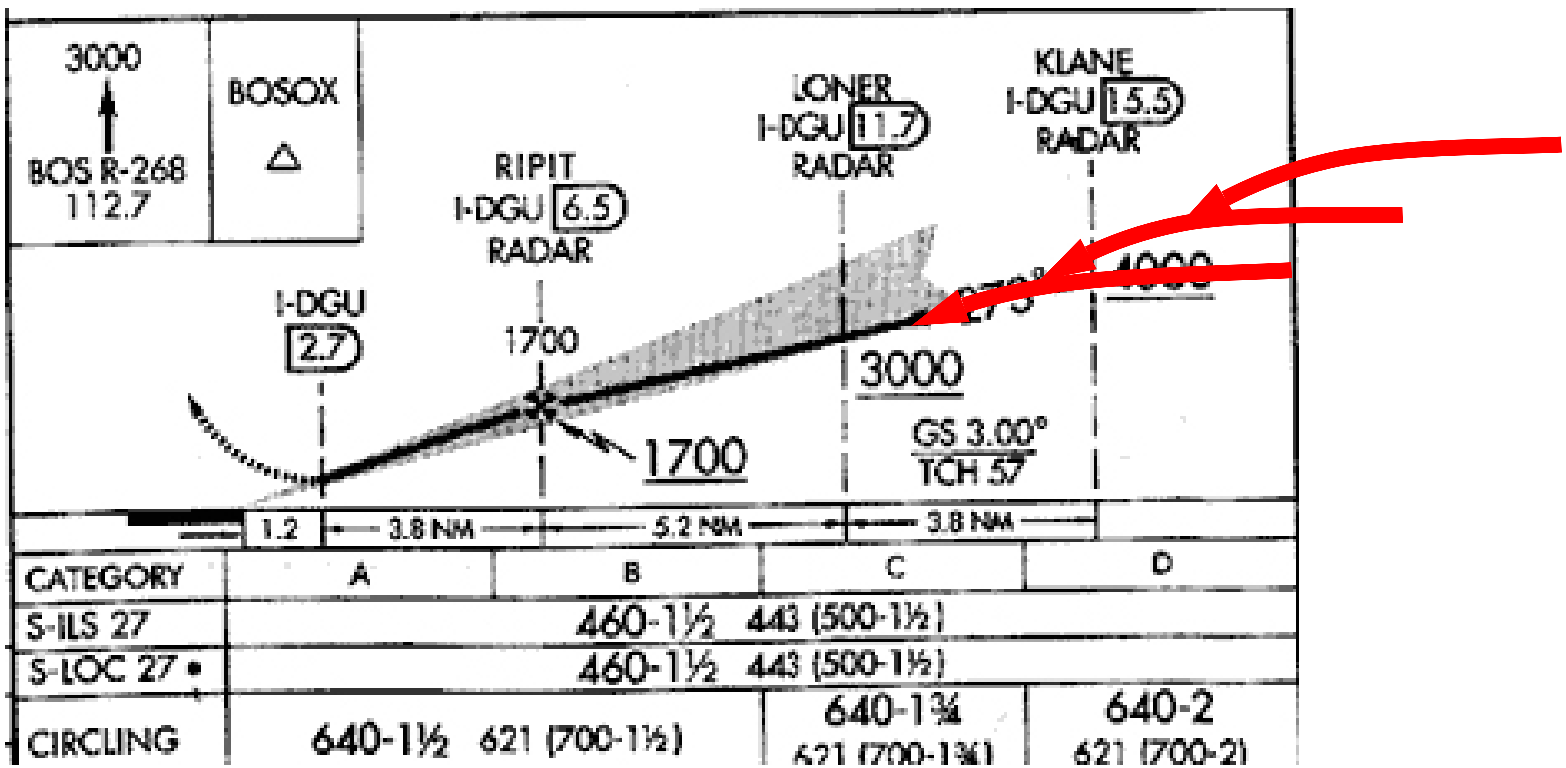
Controllers reduce the complexity of the projection task through application of structure, which reduces the 4-D projection task to a lower dimension projection task

Effect of Lateral Structure



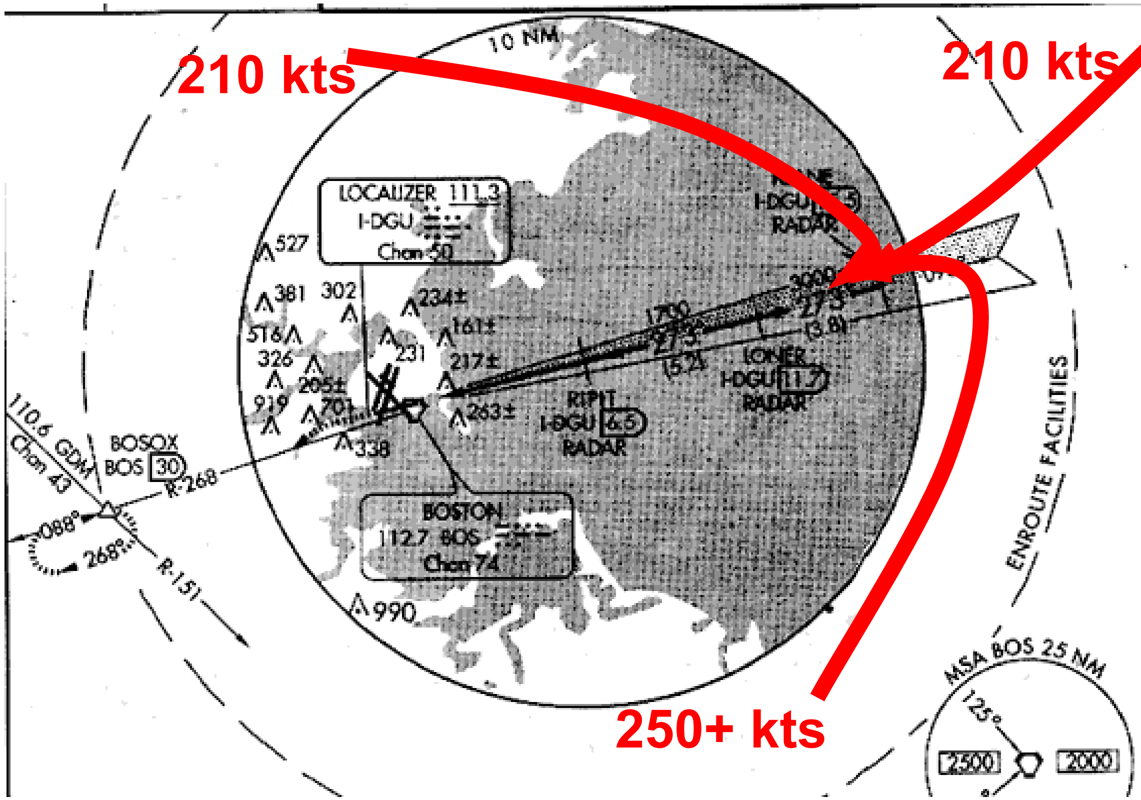
- Standard routing reduces possible lateral trajectories in time from infinite to 3 or 4 options (depending on aircraft type & runway config.)

Effect of Vertical Structure



- Approach plate altitudes & standard altitude feeds from other sectors reduce possible vertical trajectories from infinite to between 1-6

Effect of Structured Velocity



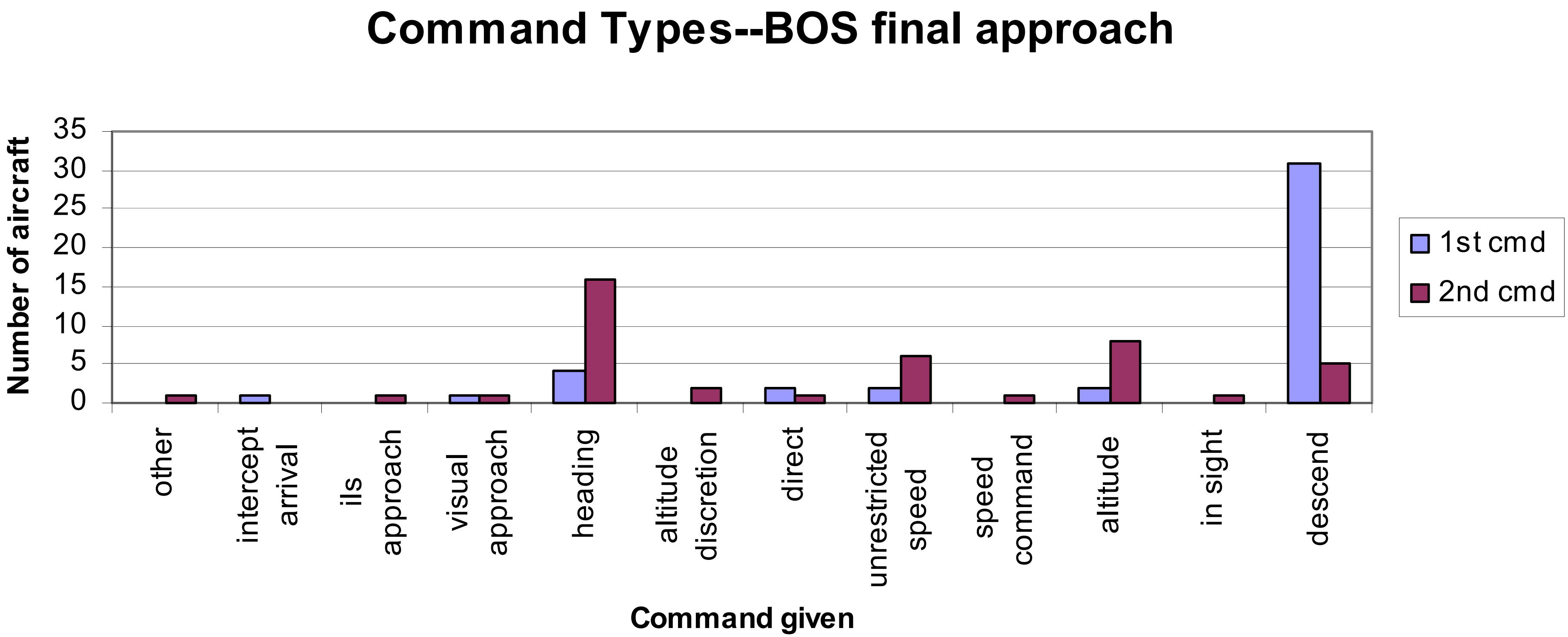
- Proceduralized approach speeds reduce the possible velocities of the aircraft from 0-600 kts to 1 speed

Effect of Structure on Aircraft Dynamics Projection

$$\begin{pmatrix} \left.\begin{matrix} P(x) \\ P(y) \end{matrix}\right\} = \begin{matrix}\text{Standard} \\ \text{Lateral} \\ \text{Route}\end{matrix} \\ \\ P(z) = \begin{matrix}\text{1 of 6} \\ \text{assigned} \\ \text{standard} \\ \text{altitudes}\end{matrix} \end{pmatrix} + \begin{pmatrix} \left.\begin{matrix} V(x) \\ V(y) \end{matrix}\right\} = \begin{matrix}\text{Assigned} \\ \text{speed}\end{matrix} \\ \\ V(z)=0 \end{pmatrix} \Delta t$$

- In a nominal trajectory, the structure provided allows the controller to use (in the simplest case) a linear 1-D projection to determine future position of the aircraft

Voice Analysis Results



- Speed structured by feed controller
- Structure was immediately imposed on aircraft in vertical domain (most frequently the 1st command given) then in the lateral domain (most frequent 2nd command given)

Future Work

- Further Voice Communications Analyses
- Experimental tests of hypothesis:
  - Perform experiment measuring controllers' performance controlling simulated air traffic under varying levels of structure
- Use findings to increase effectiveness of the design of
  - Decision support tools
  - Information systems
  - Restructured airspace